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Utility Patent Application (Provisional)

TITLE: INTERCHANGEABLE METALLIZED FILM ELECTROMAGNETIC RADIATION REFLECTOR

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REFERENCES CITED

U.S. PATENT DOCUMENTS

4,126,123	2/1977	Hall
7,013,887	7/2006	Kuckelkorn et al.
7,997,264	1/2007	Sankrithi
2012/0167949 A1	12/2011	Dentinger et al.
2010/0224232	3/2010	Cummings et al.
9,285,139 B2	7/2011	Page et al.
2014/0352756 A1	5/2014	Lamkin et al.
8,074,638 B2	8/2007	Cummings
6,886,339 B2	5/2003	Carroll et al.
6,653,551 B2	10/2002	Chen
9,033,274 B2	5/2015	DeVaul et. al.
7,859,479 B2	8/2008	Legare et al.
7,133,001 B2	11/2004	Mrstik et al.
10,696,428 B2	7/2016	Pellegrino et al.
9,995,507 B2	4/2009	Norman et al.
7,595,769 B2	2/2006	Samir F. Bassily
2009/0195882 A1	2/2008	Bolle et al.
7,646,544 B2	5/2006	Batchko et al.
6,679,611 B2	10/2002	Howard
2014/0368939 A1	17/2013	Andreasen
9,383,575 B2	7/2013	Andreasen

ABSTRACT

The electromagnetic (EM) radiation reflector disclosed utilizes metalized film or mylar for the reflective, incident surface, and focuses EM radiation (solar, radio wave, microwave, visible, etc.) onto a heat exchanger, photovoltaic cell, or secondary mirrors/lenses/devices. The metalized film obtains a light-focusing geometry, in some embodiments approximating parabolic or spherical mirrors, by first cutting out 2D Gores and attaching them together via heat or adhesive. Then the film is placed over a frame, which may consist of but is not limited to steel tubing, wood, carbon fiber, fiber glass, or plastic tubing, and subsequently pulling a partial vacuum. The frame is easy to assemble, and construction of the collector is like that of a greenhouse that uses plastic film and a steel frame for structure. In one embodiment, once the film starts degrading, it can be removed, and new film can easily be attached to the frame with magnetic assistance. Some embodiments are actuated by low-cost stepper motors and timing belts in tension, which sit on ball rollers or spherical bearings. Other embodiments use worm gear drives or other non-back-drivable mechanisms, which lowers the torque requirements for the motor. Applications for the invention include but are not limited to: concentrated solar power, directional antennas, wireless power transfer, and telescopes. Some of the primary advantages of this invention over existing technologies are: light-weight, low-cost materials, easily interchangeable parts, lower-torque requirements, and ease of construction, amongst others.

BACKGROUND

Because the invention is an electromagnetic radiation reflector and electromagnetic radiation can span from radio waves and microwaves to solar radiation and visible light, there are four important applications, among other applications, that this technology can be applied to: concentrating solar power, directional antennas, wireless power transfer, and telescopes.

Concentrating Solar Power: In the past decade, photovoltaic panels have plummeted in price, while concentrated solar power (solar Stirling engines, solar power towers, etc.) have yet to see equivalent declines in price. Unfortunately, where solar panels have roughly 20% efficiency in thermal applications, such as in the recycling of steel or the desalination of water, concentrated solar power has roughly an 80% efficiency, which translates to requiring ¼ the land for the same output. Additionally, most concentrating solar power systems have built-in thermal storage, which enables them to work at night and when the sun is not shining.

Despite these advantages, the primary reason for these cost disparities is because solar panels benefit from modularity and economies of scale and can easily be adapted to both rooftop and utility scale instillations, while concentrated solar plants are typically built in massive, custom instillations. Another reason is because the heliostats - the actual mirrors and motors that concentrate sunlight – consist of: fragile and heavy glass mirrors, a welded steel frame, and high torque motors to compensate the wind load. These heliostats make up 40-50% of the total cost of a typical solar installation, so bringing down their cost could reduce prices significantly.

To combat these issues, recent innovations in the field include using metallized polymer films (mylars) to reflect sunlight instead of glass mirrors; this reduces both the cost and weight of the system. Some inventions that make use of metallized film: create inflatable structures, lay the film on stamped sheet metal (satellite dishes), or create concave shapes by pulling a vacuum on the mylar film. However, all these methods of using mylar have notable flaws. Any balloon-

structure not only imparts significant wind drag but also loses ~20% of the incoming infrared radiation to the clear film used to construct the balloon. Stamped sheet metal structures also suffer from high cost and weight associated with traditional heliostats. Additionally, all heliostats that use mylar suffer from losses in reflective efficiency due to degradation of the mylar. Regardless of the material, over time abrasive particles carried by the wind or cleaning solutions, will mar the surface of the mylar. As the mylar is a structural components of balloon heliostats, this can be a significant design flaw. Therefore, what is needed is a way to seamlessly interchange the mylar films once they degrade. This method needs to not interfere with energy production and be simple enough that the labor costs from maintenance do not offset the performance gains.

On a similar note, maintenance and the labor of installation is a significant factor in the cost of both conventional glass heliostats and newer mylar heliostats. Most of these heliostats consist of welded frames that need to be assembled onsite by skilled tradesmen, and the ones that are assembled in factory necessitate high shipping costs. Therefore, there is a need to create heliostats that are compact to ship but also can be assembled onsite or in a factory by unskilled workers or robots to reduce costs. This is particularly important in the increasingly growing market for small-scale rural solar installations where the infrastructure does not exist to ship large objects or do significant welding work.

Directional Antennas: Radio waves, microwaves, and other signals used in communication reflect off metallic surfaces and dielectrics to direct signals from transmitter to receiver. In the case where high directivity is needed, such as in point-to-point satellite communication, large parabolic antennas often meet this requirement. However, like with solar power, large parabolic antennas can be expensive to produce and install and must be engineered with significant support structure to account for their weight and wind loads.

Some antenna designs work around this by creating inflatable structures from mylar that are either tethered to the ground or suspended from a dirigible. However, all inflatable structures are subject to leaks and mechanical failures that require costly maintenance. Other designs use a metal or composite wire mesh instead of the conventional stamped metal parabolic dish, but such designs require significant welding and impose new manufacturing, shipping, and communications challenges.

Wireless Power Transfer: One of the first demonstrations of wireless power was the 1975 NASA JPL Goldstone demonstration. Like with RF Communications, the most efficient forms of wireless power transfer use radio waves, microwaves, and similar high-gain directional antenna infrastructure but at much higher power. A lightweight deployable EM Radiation reflector would allow for applications where batteries lack sufficient energy density such as electric aircraft, drones, and space-based solar power. With a lightweight, mid-to-long distance wireless power system, it would allow for drones and aircraft that never need to land, which opens up many new potential applications.

Telescopes: Glass telescopes on the order of a meter may cost on the order of $100,000 and bigger telescopes are required each year to peer deeper into the observable universe. To create very large mirrors on the order of multiple meters at a fraction of the cost, two approaches have been pursued: liquid mirror telescopes and mylar telescopes controlled by a combination of pneumatics, electrostatics, and electromagnetism. While both approaches may in theory and in practice yield mirrors that are both low cost and can have adjustable focal lengths, both methods rely on a grid or array of electrodes or electromagnets for fine control of the optical surface. Additionally, for mylar telescopes proposed by both Howard and Andreasen, the initial shape

pulled by the vacuum would be closer to a part of a sphere or catenary, which is why electrodes are required to correct the shape into a parabola. If instead, the film started out in a parabolic shape instead of a flat sheet, this would reduce or eliminate the need for electrostatic correction. Unfortunately, this would also have the detriment of creating an upper limit on the focal length of the mirror.

SUMMARY

It is an object of the present invention to fulfill the power and temperature generating requirements of conventional heliostat mirrors, including those that are paraboloidal, parabolic, and spherical, by creating a simple to assemble frame and metallized film electromagnetic collector that has mechanisms for easily interchanging parts and whose optical shape is achieved by first assembling a 3D mirror surface from 2D gores and then adjusting the air-pressure and tension on mylar film via a partial vacuum. It is another object of the invention to create a light-weight reflector that can be used for high-directionality antennas in RF Communications and wireless power transfer and that has parts which snap or screw together without the need for welding. It is another object of the invention to have a single or multi-axis tracking mechanism that makes use of a combination of back-driving, non-back-driving, geared, and ungeared actuators, which may consist of but are not limited to stepper motors, worm gear drives, clutches, rachet and pawls, and disc or drum brakes, for tracking objects which may consist of but are not limited to: celestial bodies, other reflectors or antennas, and moving bodies.

In one embodiment of the invention, the mirrored surface consists of mylar cut in gores, like that of a balloon or blimp, and sealed together via heat or adhesive. The mylar is then pulled over a steel frame with the help of magnetic tape and bolts to hold the mylar into position. The steel frame snaps together using inserts, which fit inside of the steel tubing, and can be made of but are not limited to: polycarbonate, epoxy resin, cast iron, cast aluminum, etc. Additional parts are bolted together to maintain rigidity and dimensional accuracy. A partial vacuum is pulled to hold the mylar taught and generate a more perfect parabolic shape. Functioning as a heliostat, the reflector aligns its optical axis with the sun with the help of an inertial mass unit and accelerometer (IMU) along its optical axis, in conjunction with a solar positioning algorithm that accounts for time, latitude, and longitude. Two worm-geared motors actuate its azimuthal and elevation angles and prevent wind loads or other outside forces from back-driving the actuators.

In other embodiments of the invention, the frame may be of solid rods of material or square, circular, or other geometric tubing or wire mesh. Instead of magnetically snapping the mylar film into position, plastic tabs or clamps may be used, tensioning wire or rubber may be used, or electrostatics may be employed. Instead of worm-geared motors, other types of motors, including stepper motors with timing belts attached to the frame of the reflector, can control the reflectors elevation and azimuth angles. Additionally, limit switches or other sensors including but not limited to photovoltaic sensors, RF Antennas, etc. may be used to position the optical axis. Alternatively, if bolts and tube inserts do not supply sufficient strength, the frame may be welded or adhered together but constructed such that they can easily be stacked during shipping to reduce costs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG **1** shows an isotropic view of one embodiment of the reflector when it is acting as a heliostat

FIG **2** shows the front view of one embodiment of the reflector when it is acting as a heliostat

FIG **3** shows the side view of one embodiment of the reflector when it is acting as a heliostat

FIG **4** shows the top view of one embodiment of the reflector when it is acting as a heliostat

FIG **5** shows a detailed view of one embodiment of the reflector's actuating subsystem system when it is acting as a heliostat

FIG **6** shows a side view of one embodiment of the reflector when it is not attached to the rest of the actuating system

FIG **7** shows a section view of one embodiment of the reflector when it is not attached to the rest of the actuating system

FIG **8** shows the software flowchart of one embodiment of the reflector as a heliostat

DETAILED DESCRIPTION

One embodiment of the invention as a heliostat can generally be seen in FIG **1**, FIG **2**, FIG **3**, FIG **4**, FIG **5**, FIG **6**, and FIG **7**. In the embodiment in FIG **1**. The reflector's frame is made of ¾" steel pipe **1** bent in a 2 meter diameter but can use pipe or tubing made of a variety of materials such as HDPE, aluminum, wood, etc. and can vary in dimension. At or near the focus of the reflector is a copper heat exchanger **2** coated black to absorb the focused sunlight. However, in other embodiments the heat exchanger can be replaced with a variety of other devices including: photovoltaic panels, secondary mirrors or lenses, RF/Microwave generators or receivers, etc. The system is actuated by an assembly of geared motors, brackets, and bearings **3**. In this embodiment, the assembly is made of worm gear motors and 3D printed parts with an accelerometer along the optical axis for orienting the system. However, in other embodiments, the motors may be stepper motors, brushless motors, or other actuators and may be attached to timing belts that are attached to the perimeter of the steel structure **1** or at any other point in the structure. Additionally, instead of an accelerometer, other positional sensors can be used such as limit switches or an external camera.

The counterweights for the solar collector **4** consist of 2" steel pipe filled with sand but may consist of any mass that can put the center of mass of the structure at or near the axes of rotation of the elevation angle actuator. The entire system is supported by a square steel tube **5** that is buried halfway into the ground to support the system. However, the steel tube may be replaced by multiple smaller tubes and can be made of other materials such as wood or plastic in other embodiments. The Electronics box **6** is mounted to the steel tube **5** and may consist of but is not limited to a microcontroller, motor drivers, and power units. In other embodiments, the electronics may be distributed throughout the system or may be located anywhere else in the structure. Other embodiments may use a solar panel for energy generation or may be integrated into the grid. Additionally, the device could get data wirelessly or work autonomously or be sent data over a wired connection in other embodiments.

In one embodiment, mylar or metallized polymer film **7** covers the steel frame and provides an airtight seal. The mylar attaches to the steel frame **1** using either magnetic tape or adhesive or nuts and bolts or an elastic or tightened wire or band or some other method. The mylar is assembled by cutting out 2D gores and either glued, stitched, or heat sealed together.

Alternatively, the mylar may be assembled using magnetic tapes. Counterweight caps **8** seal the sand or weighted material in the steel counterweight tubes **9**. This allows the counterweights to be finely adjusted and filled with onsite material to reduce shipping costs. However, other embodiments may use other masses as counterweights.

The mylar or metallized film on the front of the reflector **10** provides the optical surface of the reflector, which can reflect radio waves, microwaves, and other electromagnetic radiation, but reflects sunlight in this embodiment. The mylar is cut in 2D gores that when attached together and pulled taught from a partial vacuum assemble into a parabola. The geometry of these shapes are found by modeling the 3D shape and flattening it in computer aided design software. However, due to stretching of the material, the exact shape will likely be iteratively found through experimentation. The heat exchanger **2** is supported by steel rods **11** that attach to the perimeter of the steel frame. In other embodiments, the steel rods may be replaced with steel tubes or tubing and rods made of other materials such as carbon fiber, plastic, aluminum, or wood. The steel rods **11** may be greater or less in number than that shown in FIG **3**.

The backplate **12** seen in FIG **4** may be rigid and constructed of an aluminum, steel, plastic, or wood plate or a plate made of another material with an airtight seal with the steel frame. Alternatively, the backplate may also be made of mylar. There is a port, which is not modeled, within the backplate that connects to a vacuum pump and gauge pressure sensor. These are used to regulate the vacuum within the structure, mitigating the effects of air leaks, and keeping the mylar taught with fluctuating atmospheric pressure. Alternatively, in other embodiments, there may be multiple ports that exist throughout the structure.

FIG **5** is a close view of the actuating subsystem **3**. The elevation angle worm gear motor **13** controls the angle of the system with respect to the horizon while the azimuth angle worm gear motor **14** controls the system with respect to true north. In other embodiments, the motors may be replaced with bearings and the system could be actuated by timing belts attached to parts of the steel frame **1**. Other embodiments may use other actuators such as stepper motors, compressed air actuators, or linear actuators. The elevation angle worm gear motor **13** attaches to the steel structure of the reflector via a bracket **15**. In this embodiment the accelerometer, not modeled, is attached to the bracket along the optical axis. The bracket **15** attaches via flange mounted brackets **16** to the shafts supported by the top cap **17**, which is supported by a thrust bearing **18**. The shaft **19** that rotates the bracket **15** is attached to the elevation angle worm gear motor **13** via a shaft coupler **20**. Other embodiments may have different combinations of shafts, bearings, and couplers to support the system to allow for rotation of the reflector along either the elevation angle, the azimuth angle, or both.

FIG **6** shows a closer view of the reflector. The holes in the steel tubing **21** are for nuts and bolts. These are used to secure the structure together and may act to hold the mylar in place. Alternatively, instead of nuts and bolts, the steel pipe **1** may be press fit together with inserts, welded together, or attached in some other manner. FIG **7** shows a section view of the reflector where the plastic inserts **22 23** can be seen within the steel tubing. These inserts can be made of steel or aluminum, or other material. The inserts **22 23** are press-fit into the tubing and may be permanently attached with adhesive or nuts and bolts. Alternatively, small holes may be drilled within the tubing to allow for the inserts to snap into place and not require any additional assembly. These inserts **22 23** may be structural components that links the entire structure together or merely components that guide the final assembly of the structure when welded or assembled using some other method. The inserts on the top part of the reflector **22** also act to hold in place the steel rods **11**.

FIG **8** depicts one software flowchart for an embodiment of the invention as a heliostat. First the GPS and calibration data are entered into the system via a user interface or hardcoded. When the system starts, it first checks if it is nighttime or if there is inclement weather. If either condition is met, it positions the system to a position that reduces the wind force on the system to prevent wear and damage. The system also checks the gauge pressure on the pressure sensor within the partial vacuum. It adjusts this using a small vacuum pump based on changes in the external atmospheric pressure and any leaks in the system. If there is no inclement weather and it is during daytime, the system uses the current time, its GPS coordinates, and its orientation data to position the optical axis of the collector towards the sun. Based on how hot the collector is, the flowrate of the working fluid is adjusted and vice versa. Other embodiments may have a nearly limitless variation in software workflows that allow the system to achieve a variety of functions such as tracking celestial or moving bodies and may use a variety of inputs and sensors.

CLAIMS

While one embodiment of the invention has been detailed with references to the attached Figures, for those skilled in the art, other embodiments and variations of the invention are possible within the scope and spirit of the invention.

What is claimed:

1. An electromagnetic radiation reflector comprising:

A rigid frame consisting of metal, composite, polymer, or ceramic tubing and/or wire;
A metallized or dielectric polymer, graphene, or glass mirror constructed from 2D gores;
A partial vacuum to pull those gores into a paraboloidal surface;
A length of magnetized tape on the mirror film to allow for the quick interchanging of films after wear or for cleaning;
An assortment of polymer, metal, ceramic, or composite inserts that allow for quick assembly of the reflector and secure the components in place;
A secondary surface that the electromagnetic waves are directed towards;

2. The reflector of claim 1 in which the system is actuated by motors with or without gears in conjunction with timing belts attached to the frame of the structure
3. The reflector of claim 1 in which the system is actuated by motors with non-back drivable mechanisms to reduce torque requirements of the motors
4. The reflector of claim 1 in which the system is actuated by back drivable motors
5. The reflector of claim 1 in which the partial vacuum is regulated using a pump
6. The reflector of claim 1 in which the orientation of the reflector is calculated using input by sensors such as accelerometers, gyroscopes, magnetometers, optical sensors, real time clocks, voltage sensors, etc.
7. The reflector of claim 1 in which the orientation of the reflector is determined via a combination of programmed information and signals sent over wired or wireless communication
8. The reflector of claim 1 in which the reflectors electronics receive power by renewable resources such as solar photovoltaic, thermoelectric, wind-powered, etc., which are mounted on or within the rigid frame.
9. The reflector of claim 1 in which the frame may be inflated or supported by differences in air pressure

10. The reflector of claim 1 in which electromagnetic waves are focused onto a secondary surface that consists of an energy conversion device such as photovoltaic cells, thermo-electric generators, or a heat exchanger.

11. The reflector of claim 1 in which electromagnetic waves are focused onto a secondary surface located away from the structure that is stationary such as a solar power tower

12. The reflector of claim 1 in which electromagnetic waves are focused onto a secondary surface located away from the structure that is moving such as a celestial body or satellite

13. The reflector of claim 1 in which the electromagnetic waves are focused onto a secondary mirror or lens

13. The reflector of claim 1 in which the frame is attached to the ground

14. The reflector of claim 1 in which the frame is attached to a vehicle

15. The reflector of claim 1 in which the electromagnetic radiation is sunlight

16. The reflector of claim 1 in which the electromagnetic radiation is visible light, infrared light, ultraviolet light, x-rays, gamma rays, radio waves, and/or microwaves.

17. The reflector of claim 1 in which the reflecting surface has a shape of a revolved conic section

18. The reflector of claim 1 in which the film is attached to the frame using adhesive or bolts or air pressure

19. The reflector of claim 1 in which the orientation of the system is actuated by linear actuators such as a Stewart mechanism.

20. The reflector of claim 1 in which the frame is assembled using bolts, welding, adhesive, electrostatics, magnetostatics, or a combination thereof.

FIGURES

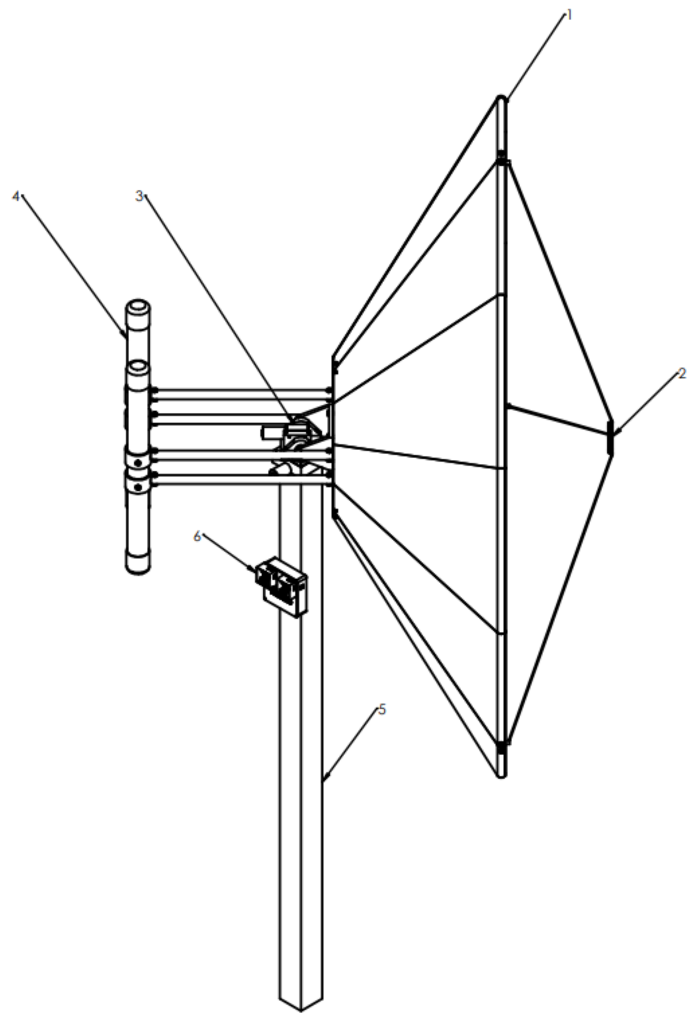

Figure 1

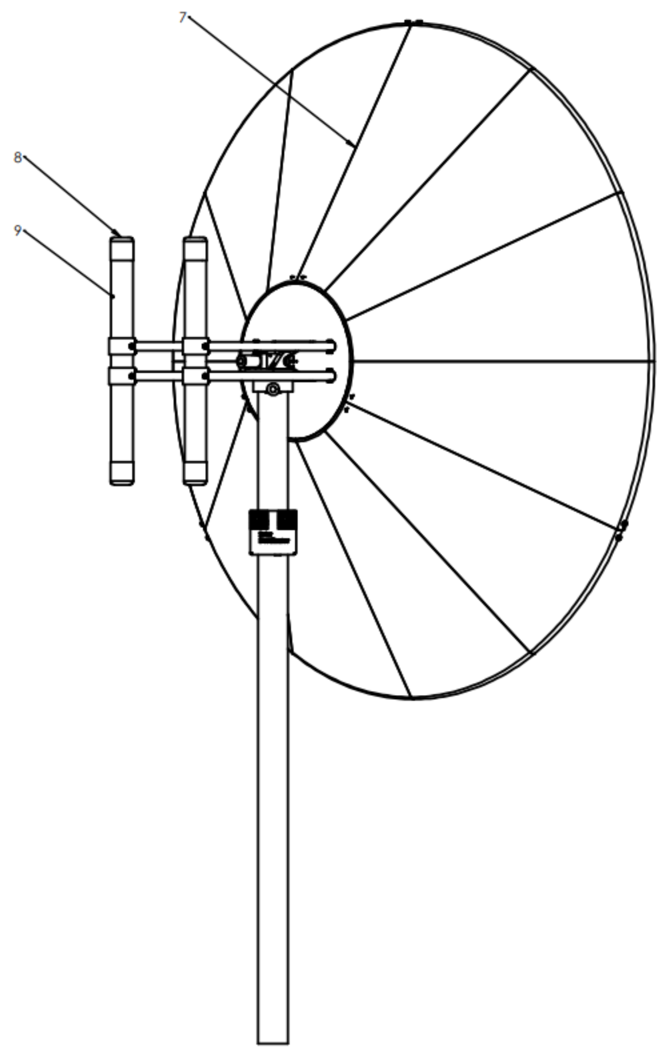

Figure 2

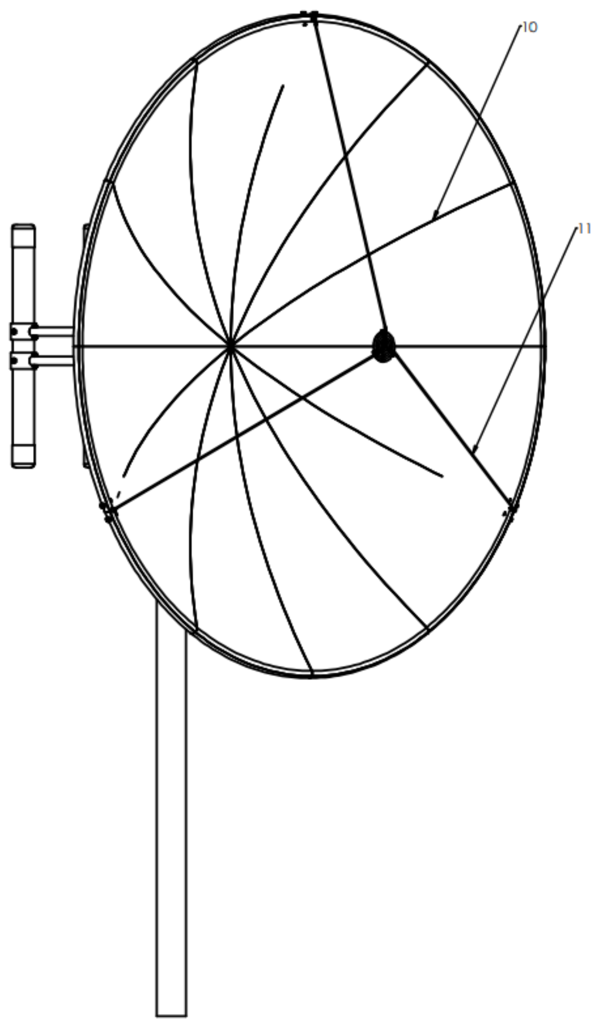

Figure 3

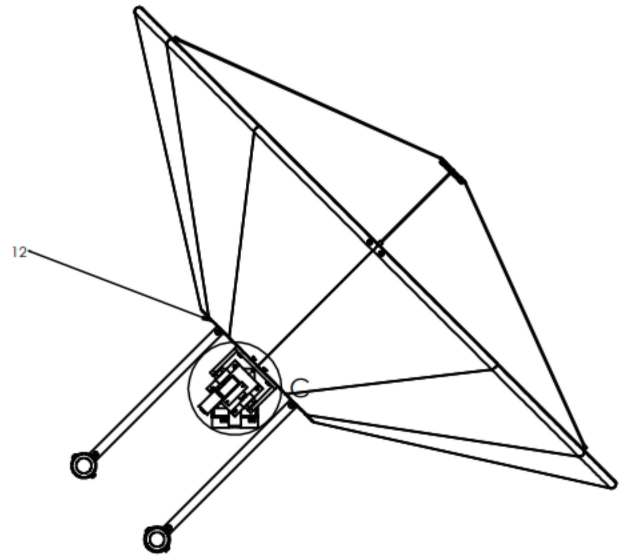

Figure 4

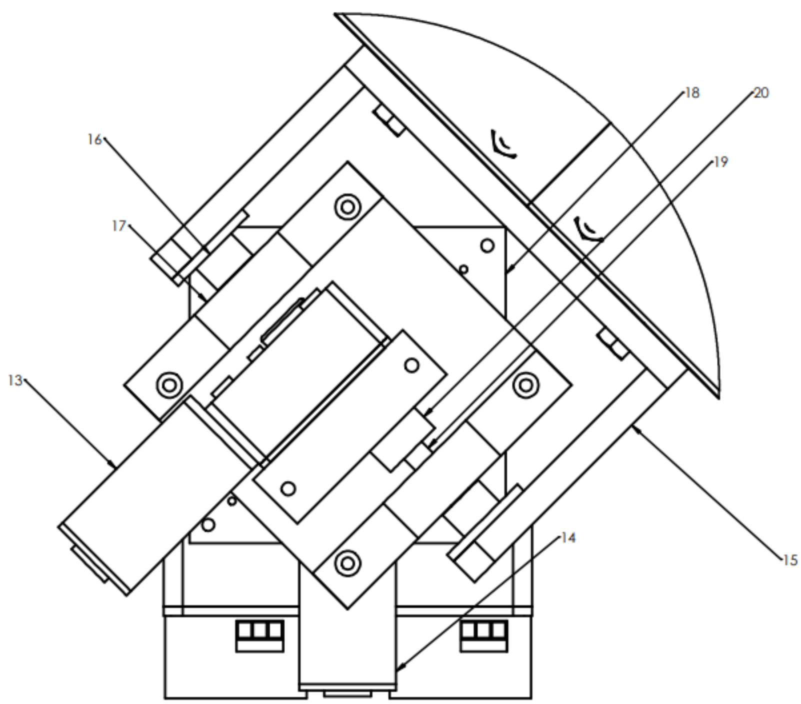

Figure 5

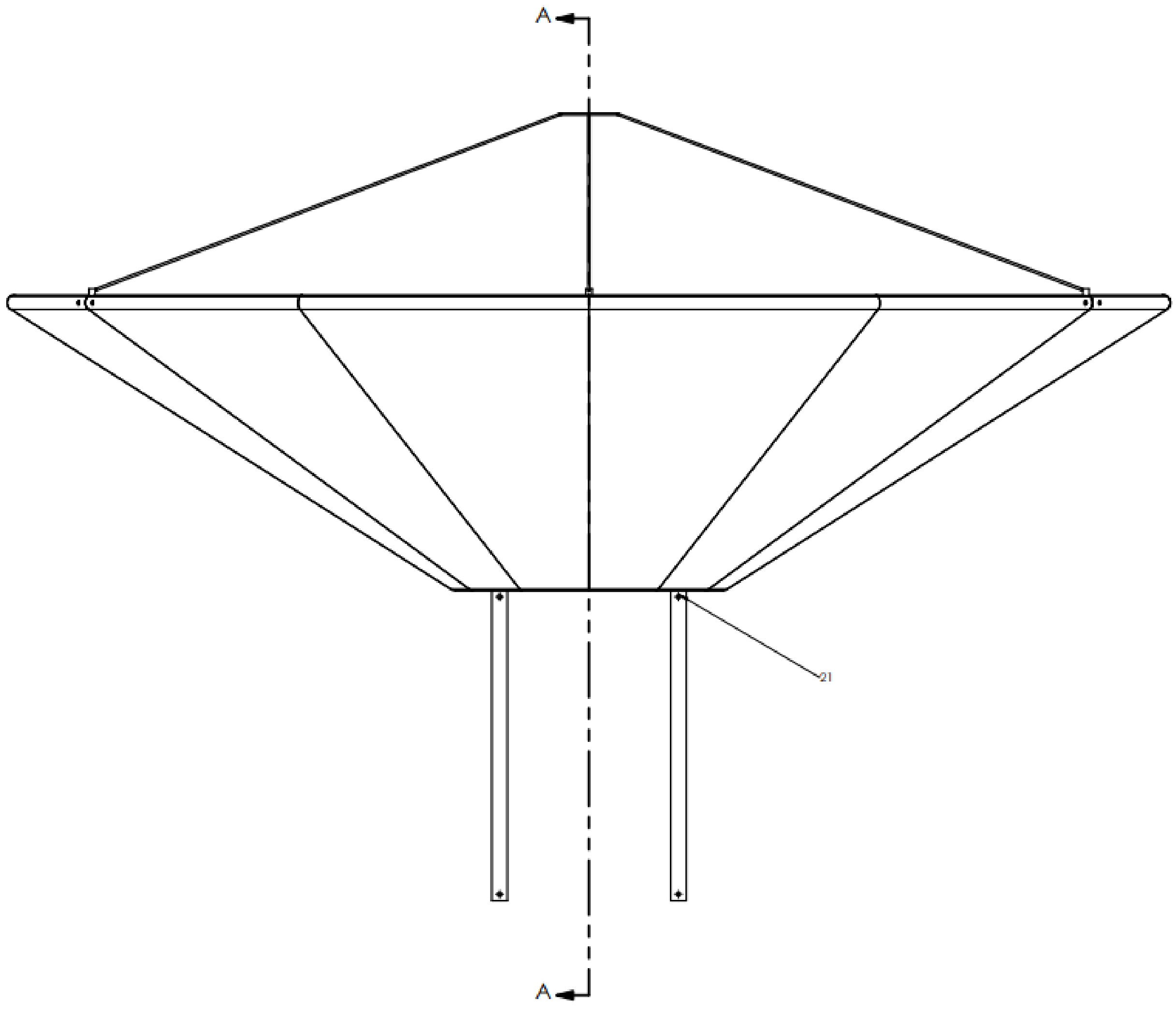

FIGURE 6

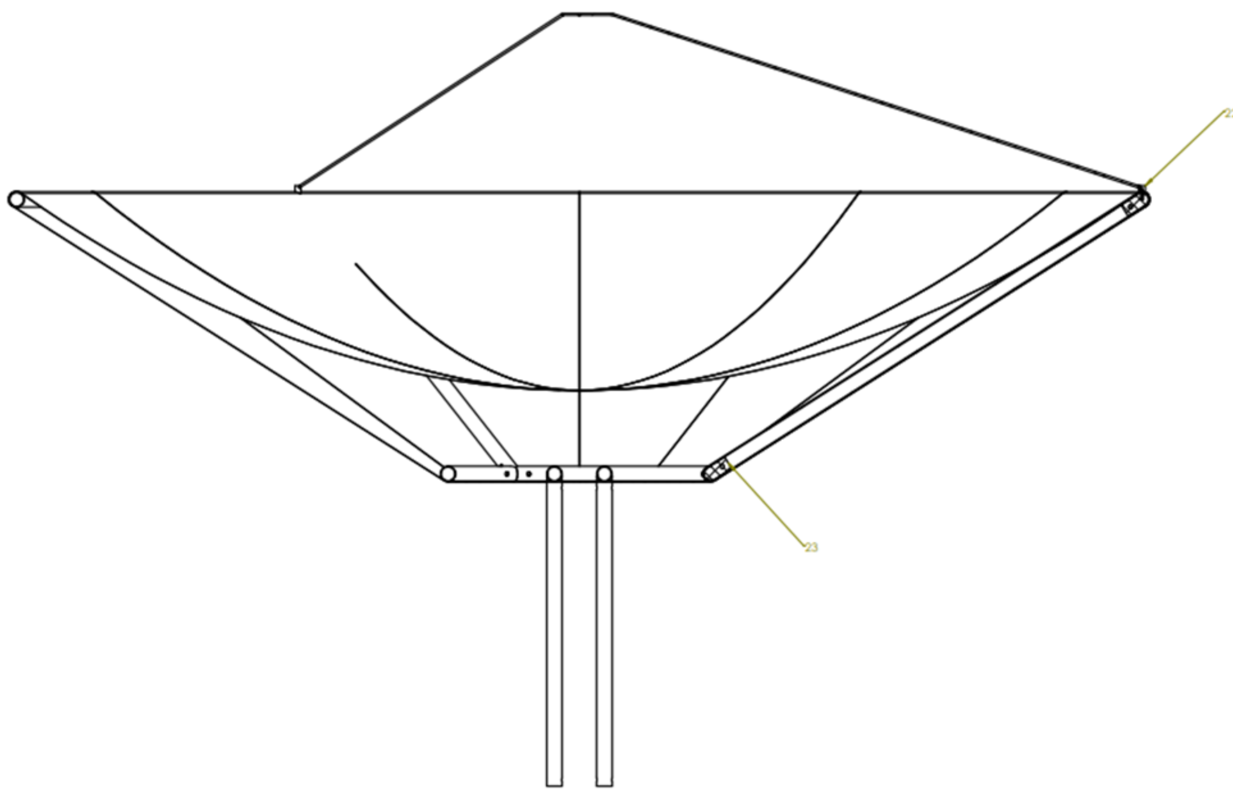

FIGURE 7

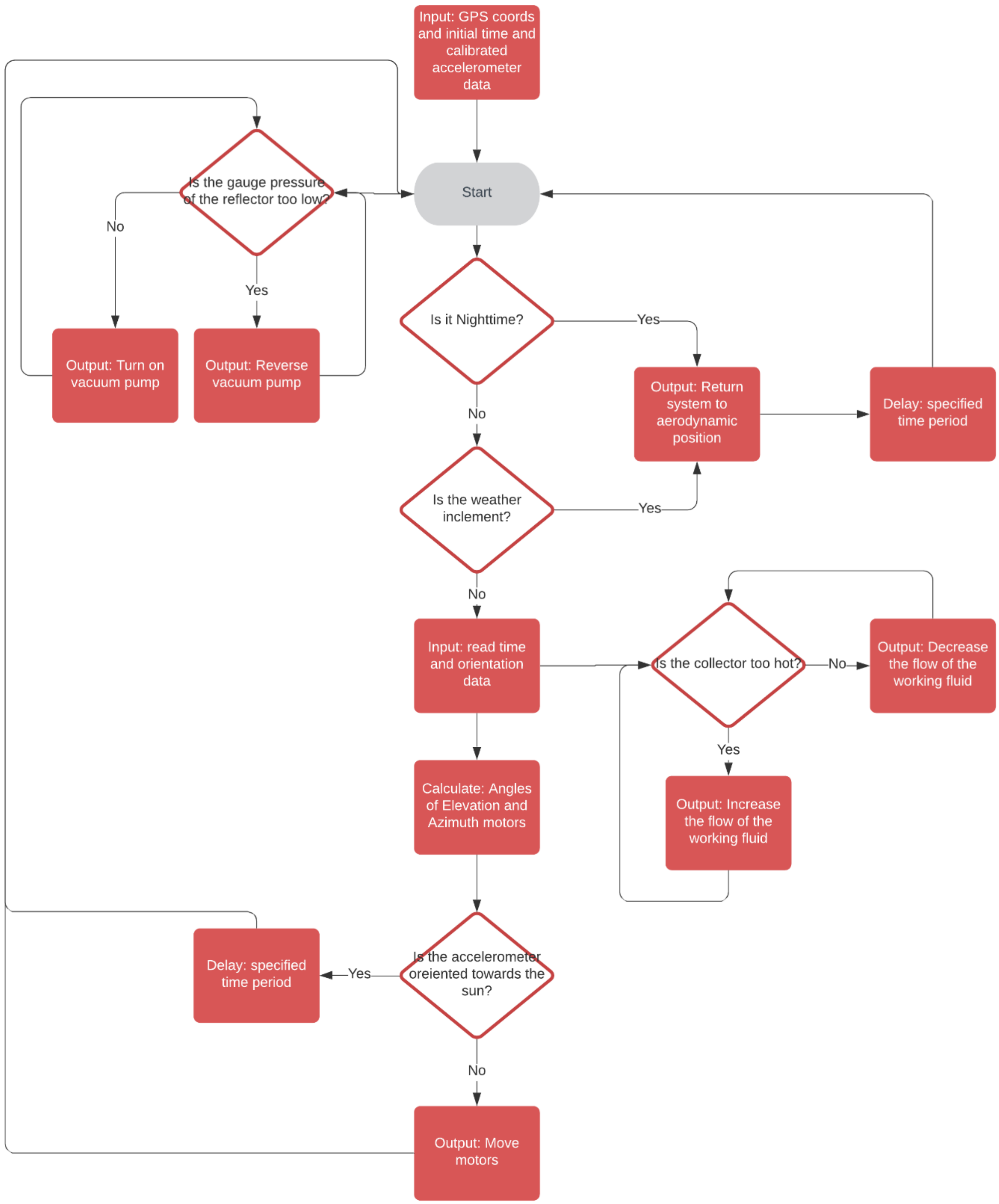
Input: GPS coords and initial time and calibrated accelerometer data
Start
Is it Nighttime?
Yes
No
Output: Return system to aerodynamic position
Delay: specified time period
Is the weather inclement?
Yes
No
Input: read time and orientation data
Is the collector too hot?
No
Yes
Output: Decrease the flow of the working fluid
Output: Increase the flow of the working fluid
Calculate: Angles of Elevation and Azimuth motors
Is the accelerometer oreiented towards the sun?
Yes
No
Delay: specified time period
Output: Move motors
Is the gauge pressure of the reflector too low?
No
Yes
Output: Turn on vacuum pump
Output: Reverse vacuum pump

FIGURE 8